Building an MP3 Player on the uClinux Operating System Using ColdFire MCF5249

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1 Introduction

MP3 content has become popular in the PC world and consumer space (portable media players, USB thumbs, hard-drive media players, automotive radio, mini systems, etc.). The ColdFire$^®$ devices MCF5249, MCF5250, and MCF5251 are effective for developing MP3 solutions due to performance, integrated audio peripherals, low power, and Freescale Semiconductor's extensive software and hardware reference designs.

This application note shows how to run an MP3 decoder on ColdFire MCF5249 using the uClinux™ operating system, a variant of Linux that runs on microprocessors without a memory management unit (MMU). Instructions also show how to install uClinux, build the MP3 player application, and play files from a remote host through the Ethernet.

After reading this note, you can build an uClinux image; download it to a M5249C3 board; install uClinux operating system and the toolchain and configure the kernel for a M5249C3 board; add an MP3 decoder application to the kernel; and export a directory from the

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host via network-file system (NFS) and play its content on the M5249C3 board.

1.1   Processor Description

The MCF5249 comes in two packages:

- 144-pin QFP — Runs up to 120 MHz
- 160-pin BGA — Runs up to 140 MHz
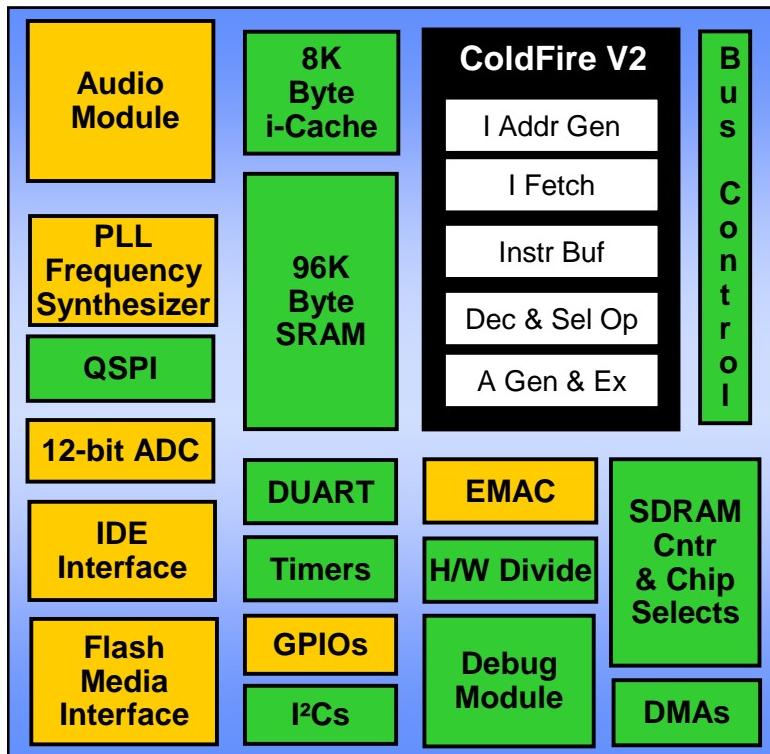
Figure 1. MCF5249 Block Diagram

Features:

- Enhanced multiply and accumulate (eMAC) unit — Allows the MCF5249 to perform digital signal processing algorithms such as vocoders used in VoIP applications (G.729, G.723) MP3, WMA, decoder, and encoding
- Internal SRAM — (96 KB on the MCF5249) Important for tasks (such as supporting the MP3 decoder) because the critical time data and program can be placed in internal SRAM, which has a faster access time than external SDRAM
- Low power consumption — (1.3 mW/MHz) Suitable for portable devices
- IDE interface — Allows glue-less connection to a hard drive
- Background debug module (BDM) — Flexible debug interface; also allows external flash programming
- Serial audio interfaces — Supports I2S and EIAJ standards
- SPDIF(IEC958) digital audio interfaces

- SD and MMC interfaces

1.2 Evaluation Board

The M5249C3 is the evaluation board for the MCF5249 and the hardware used in this document.
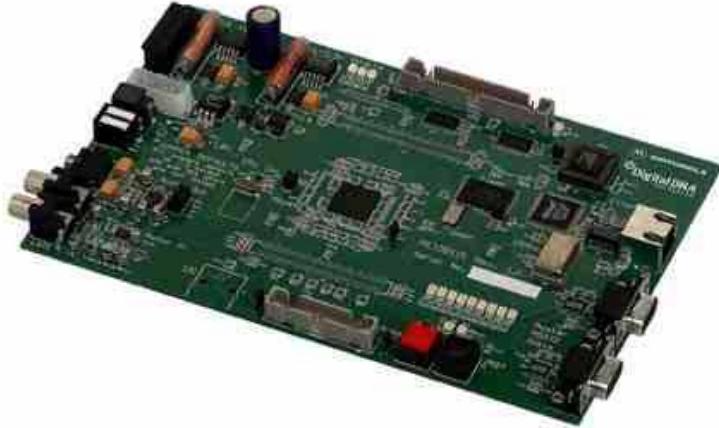
Figure 2. M5249C3 board

M5249C3 features:

- 8 MB of SDRAM
- 2 MB of flash
- External 10/100 ethernet controller
- Two serial ports — One for monitor, one for general purpose
- BDM debug module interface connector — Used with source-level debuggers running on PCs
- IDE connector for glue-less hard-drive connection
- Stereo audio inputs and stereo audio input jacks
- Pre-flashed dBug monitor firmware — Allows access to CPU registers, memory content, and the ability to download applications to the target from the serial port and over Ethernet

2 Building the Application

The following sections show how to set up the application's working environment and how to build and download the MP3 decoder to the M5249C3 under the uClinux operating system.

2.1 System Requirements

- M5249C3 board, a serial cable, and crossover cable
- A Linux host computer. The distribution used in the tests was RedHat 9.0®, but you can also run in different Linux distributions. Enable the NFS and trivial file transfer protocol (TFTP) services in the Linux host. This may vary among distributions, but activating these services is beyond this document's scope. A terminal emulator such as minicon is also needed for communicating with the M5249C3 board.

2.2   uClinux Installation Process

Installing on the host machine:

1. Download the latest uClinux distribution from http://www.uclinux.org/pub/uClinux/dist/. (This document was written when the latest version was uClinux-dist-20051110.) The current version is uClinux-dist-20060803, which is a full-source package containing kernel (2.0, 2.4, and 2.6) libraries and application code.

2. Download the toolchain for ColdFire (http://www.uclinux.org/pub/uClinux/m68k-elf-tools/). This application note uses the m68k-elf-tools-20030314. It contains the cross-compiler and assembler for ColdFire targets.

3. As root, install the toolchain in the Linux host sh m68k-elf-tools-20030314"

4. Log in as a standard user.

5. Copy the uClinux source package file uClinux-dist-200511110.tar.gz into /home/ directory, for example:/home/fabio)**.**

6. Go to /home/user directory and extract tar –xzvf uClinux-dist-200511110.tar.gz

2.2.1   Generating a uClinux Image and Downloading it to the Target

After the toolchain and uClinux distribution are installed in the host computer, build an image for the M5249C3 then download it to the board.

1. Configure the kernel and target options. Go to uClinux-dist directory, then:

    >> cd /home/user/uClinux-dist

    >> make menuconfig

   The following window should appear:
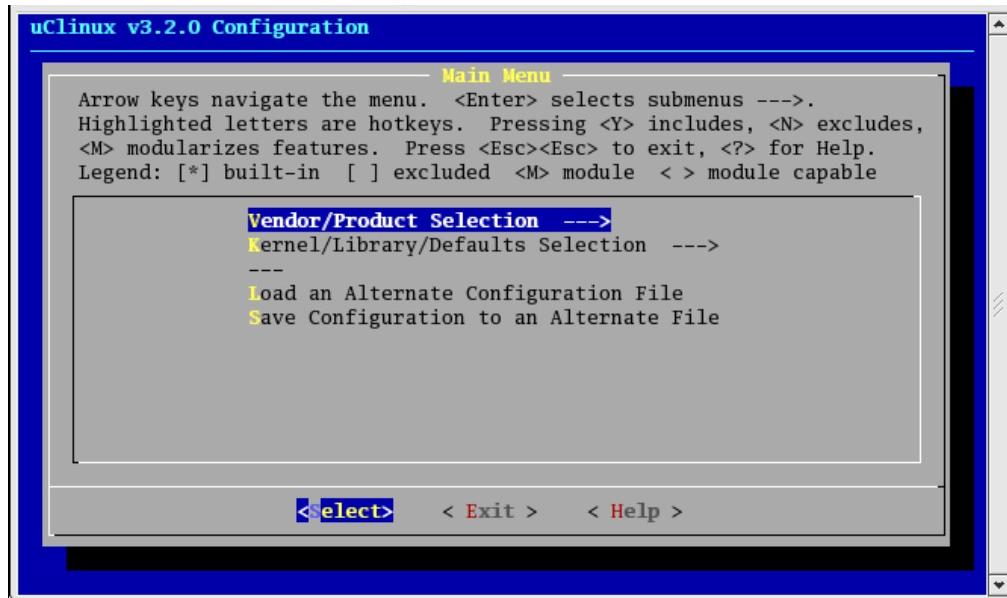
Figure 3. Menuconfig Window

2. Select vendor/settings.
3. Select the vendor and M5249C3 as the target.
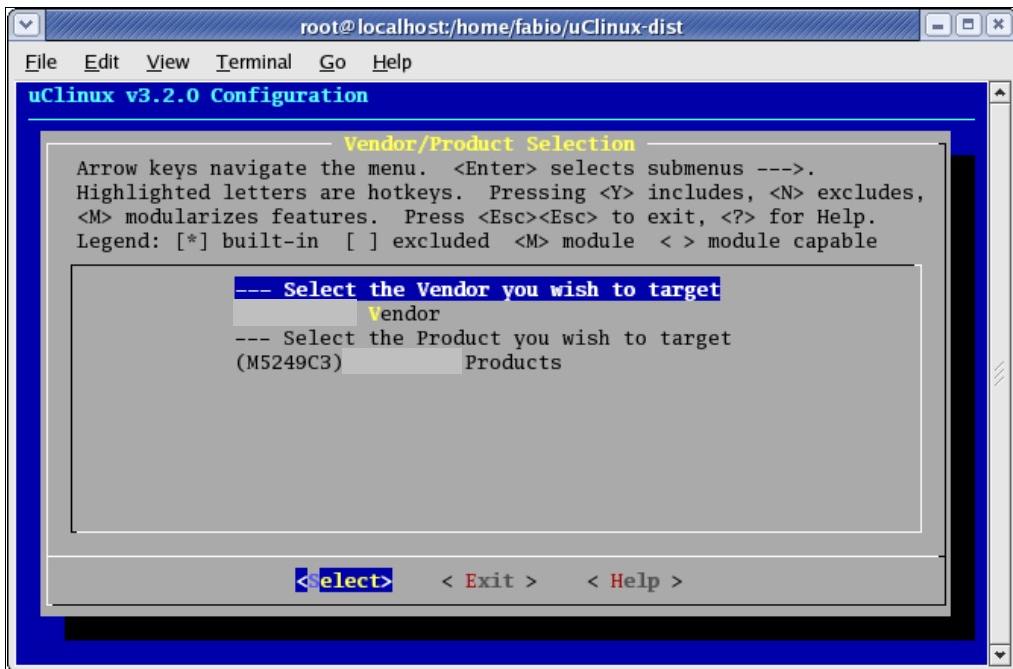
Figure 4. Vendor and Target Selection

4. Select kernel linux-2.4 and uC-lib as libc.
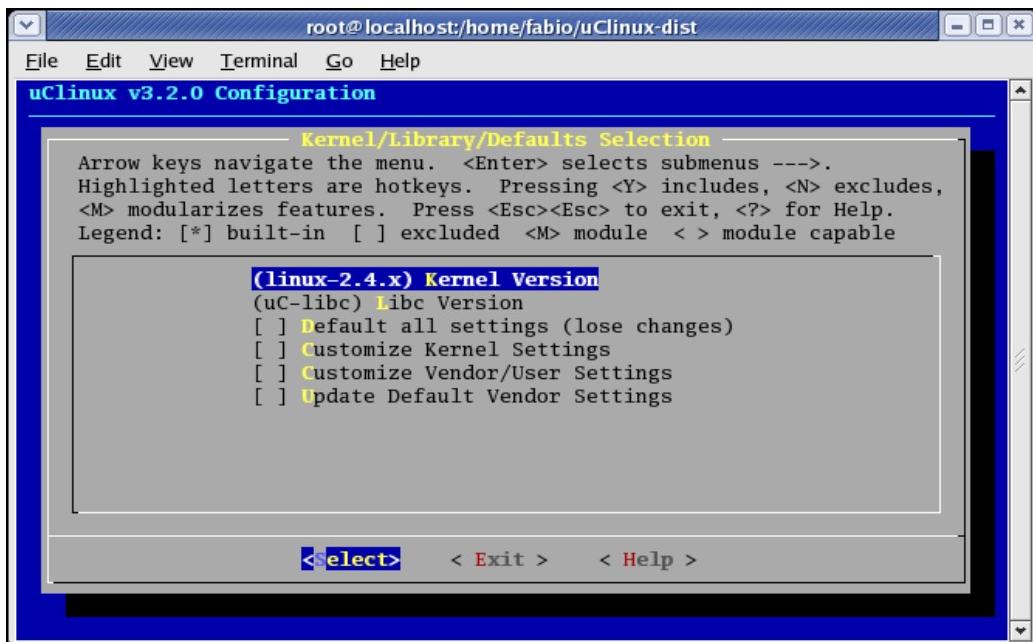
Figure 5. Kernel and Libc Selection

Building an MP3 Player on the uClinux Operating System Using ColdFire MCF5249, Rev. 0

5. Select Yes to save the kernel configuration.
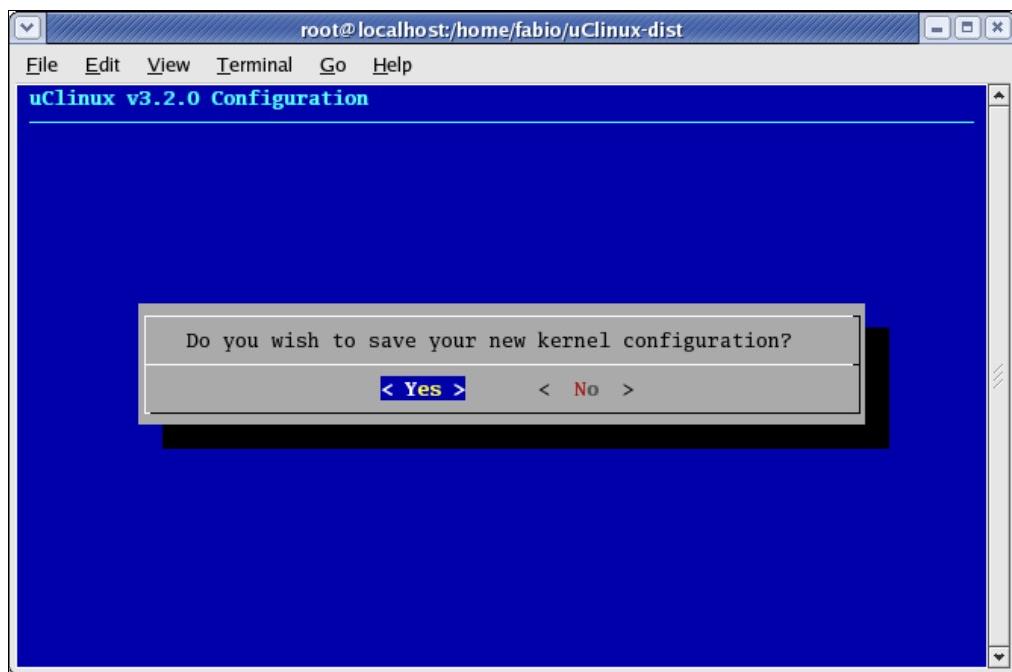
Figure 6. Save Kernel Configuration Window

6. Create a folder called /tftpboot that contains the generated image.bin file. As root (the "su" command enters in root mode):

    >>mkdir /tftpboot

    >>chmod 777 /tftpboot

    Going back to user mode (command is "su user")

    >> make dep ; make

7. After a successful build process, an image.bin file must have been placed in the /tftpboot folder. The image.bin file combines the kernel and root-file systems.

Downloading the image to the M5249C3:

1. Connect the serial cable from the host PC to the M5249C3.
2. In the host, run a terminal emulator such as minicon and set it to a baud rate of 19200 bps, 8 bits, no parity, no software and no hardware flow control.

3. Power up the M5249C3. The following messages appear:

```
Hard Reset
DRAM Size: 8M

ColdFire MCF5249 EVS Firmware
v3a.1b.1c
(Build 4 on Mar 04 2003 15:38:14)

Enter 'help' for help.
dBUG

dBUG>
```

Refer to the *M5249C3 User Manual* for a detailed list of commands supported by the dBug monitor.

Ensure that the TFTP service is enabled and that /tftpboot folder can be exported. The TFTP package is not installed by default in RedHat 9.0 and also in some other Linux distributions. In RedHat 9.0, the configuration file for TFTP server is /etc/xinetd.d/tftp (listed below):

```
service tftp
{
      disable     = no
      socket_type = dgram
      protocol    = udp
      wait              = yes
      user              = root
      server      = /usr/sbin/in.tftpd
      server_args = -s /tftpboot
      per_source  = 11
      cps               = 100 2
      flags             = IPv4
}
```

Insert a crossover cable between the host PC and the M5249C3 board.

NOTE

> You can use a normal cable and connect the PC and the M5249C3 in a network. By default, the DHCP application is enabled for the M5249C3, and the board can retrieve an IP address if the network has DHCP capability.

1. In dBug prompt, type "show"

   dBug>set server 192.168.0.1

   dBug>set client 192.168.0.2

2. In the host: ifconfig eth0 192.168.0.1

   dBug>dn –i image.bin

This command requests a TFTP transfer and sends the image.bin file located at /tftpboot folder from the host.

Building an MP3 Player on the uClinux Operating System Using ColdFire MCF5249, Rev. 0

The image transferred through TFTP is now loaded into the external SDRAM of the M5249C3. To execute the uClinux kernel, jump to its initial location, 0x20000. The command in dBug is dBug> go 20000

The kernel boot message should start:

```
Linux version 2.4.31-uc0 (root@localhost) (gcc version 2.95.3 20010315 (release)(ColdFire patches -
20010318 from http://fi6

uClinux/COLDFIRE(m5249)
COLDFIRE port done by Greg Ungerer, gerg@snapgear.com
Flat model support (C) 1998,1999 Kenneth Albanowski, D. Jeff Dionne
On node 0 totalpages: 2048
zone(0): 0 pages.
zone(1): 2048 pages.
zone(2): 0 pages.
Kernel command line:
Calibrating delay loop... 92.56 BogoMIPS
Memory available: 6052k/8192k RAM, 0k/0k ROM (775k kernel code, 221k data)
kmem_create: Forcing size word alignment - mm_struct
kmem_create: Forcing size word alignment - filp
Dentry cache hash table entries: 1024 (order: 1, 8192 bytes)
Inode cache hash table entries: 512 (order: 0, 4096 bytes)
kmem_create: Forcing size word alignment - inode_cache
Mount cache hash table entries: 512 (order: 0, 4096 bytes)
kmem_create: Forcing size word alignment - bdev_cache
kmem_create: Forcing size word alignment - cdev_cache
kmem_create: Forcing size word alignment - kiobuf
Buffer cache hash table entries: 1024 (order: 0, 4096 bytes)
Page-cache hash table entries: 2048 (order: 1, 8192 bytes)
POSIX conformance testing by UNIFIX
Linux NET4.0 for Linux 2.4
Based upon Swansea University Computer Society NET3.039
Initializing RT netlink socket
Starting kswapd
kmem_create: Forcing size word alignment - file_lock_cache
kmem_create: Forcing size word alignment - nfs_read_data
kmem_create: Forcing size word alignment - nfs_write_data
ColdFire internal UART serial driver version 1.00
ttyS0 at 0x100001c0 (irq = 73) is a builtin ColdFire UART
ttyS1 at 0x10000200 (irq = 74) is a builtin ColdFire UART
M5249AUDIO: (C) Copyright 2002, Greg Ungerer (gerg@snapgear.com)
M5249AUDIO: DMA channel=0, irq=120
Bad boy: audio(DMA) (at 0x0007ede8) called request_irq without a dev_id!
kmem_create: Forcing size word alignment - blkdev_requests
SMSC LAN91C111 Driver (v2.0), (Linux Kernel 2.4 + Support for Odd Byte) 09/24/01 -      by Pramod Bhardwaj
(pramod.bhardwaj@)eth0: SMC91C11xFD(rev:1) at 0xe0000300 IRQ:166 MEMSIZE:8192b NOWAIT:0 ADDR:
00:cf:52:49:c3:04
SLIP: version 0.8.4-NET3.019-NEWTTY (dynamic channels, max=256).
CSLIP: code copyright 1989 Regents of the University of California.
Blkmem copyright 1998,1999 D. Jeff Dionne
Blkmem copyright 1998 Kenneth Albanowski
Blkmem 1 disk images:
0: 119564-1FB163 [VIRTUAL 119564-1FB163] (RO) <ROMFS>
RAMDISK driver initialized: 16 RAM disks of 4096K size 1024 blocksize
PPP generic driver version 2.4.2
PPP MPPE compression module registered
NET4: Linux TCP/IP 1.0 for NET4.0
```

```
NET4: Unix domain sockets 1.0/SMP for Linux NET4.0.
FAT: bogus logical sector size 49024
VFS: Mounted root (romfs filesystem) readonly.
Freeing unused kernel memory: 24k freed (0xfe000 - 0x103000)
Shell invoked to run file: /etc/rc
Command: hostname uClinux
Command: /bin/expand /etc/ramfs.img /dev/ram1
Command: mount -t proc proc /proc
mount: bb_xasprintf: Unknown error 0
pid 9: failed 256
Command: mount -t ext2 /dev/ram1 /var
Command: mkdir /var/tmp
Command: mkdir /var/log
Command: mkdir /var/run
Command: mkdir /var/lock
Command: mkdir /var/empty
Command: ifconfig lo 127.0.0.1
Command: route add -net 127.0.0.0 netmask 255.0.0.0 lo
Command: dhcpcd -p -a eth0 &
[13]
Command: cat /etc/motd
Welcome to
              ____ _   _
             /  __| || |_|
      _    _| |    | | |  _ ____   _   _  _  _
     | |  | | |    | || |  _ \| | | |\ \/ /
     | |_| | |__|  || | | | | | |_| |/    \
     |  _____|_||_|_| |_|\____|\_/\_/
     | |
     |_|

For further information check:
http://www.uclinux.org/

Execution Finished, Exiting

Sash command shell (version 1.1.1)
    />
```
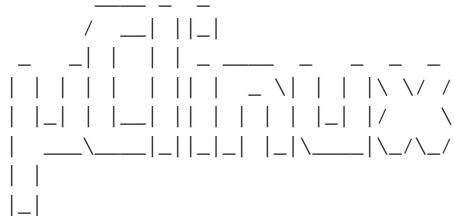
You can now manually set up the IP address of the board by "ifconfig eth0 192.168.0.2".

NOTE

If the M5249C3 is connected to a network, you can get an IP address through DHCP. The default setting of uClinux enables the DHCP daemon.

You can try to ping the host: "ping 192.168.0.1". Press "CTRL-C" to stop the ping process.

```
/> ifconfig eth0 192.168.0.2
/> ping 192.168.0.1
PING 192.168.0.1 (192.168.0.1): 56 data bytes
64 bytes from 192.168.0.1: icmp_seq=0 ttl=64 time=5.9 ms
64 bytes from 192.168.0.1: icmp_seq=1 ttl=64 time=2.9 ms
64 bytes from 192.168.0.1: icmp_seq=2 ttl=64 time=2.9 ms
64 bytes from 192.168.0.1: icmp_seq=3 ttl=64 time=2.9 ms
64 bytes from 192.168.0.1: icmp_seq=4 ttl=64 time=2.9 ms

--- 192.168.0.1 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
```

2.3   Adding the MP3 Decoder Application

2.3.1   Audio Hardware and Device Driver

Two serial audio interfaces are connected on the M5249C3 board:

- I2S1 — Can be used as input and output interface and is connected to an A/D (AK5353)
- I2S2 — Output-only interface connected to AK4360 (D/A) as shown below. Analog stereo output is J1.
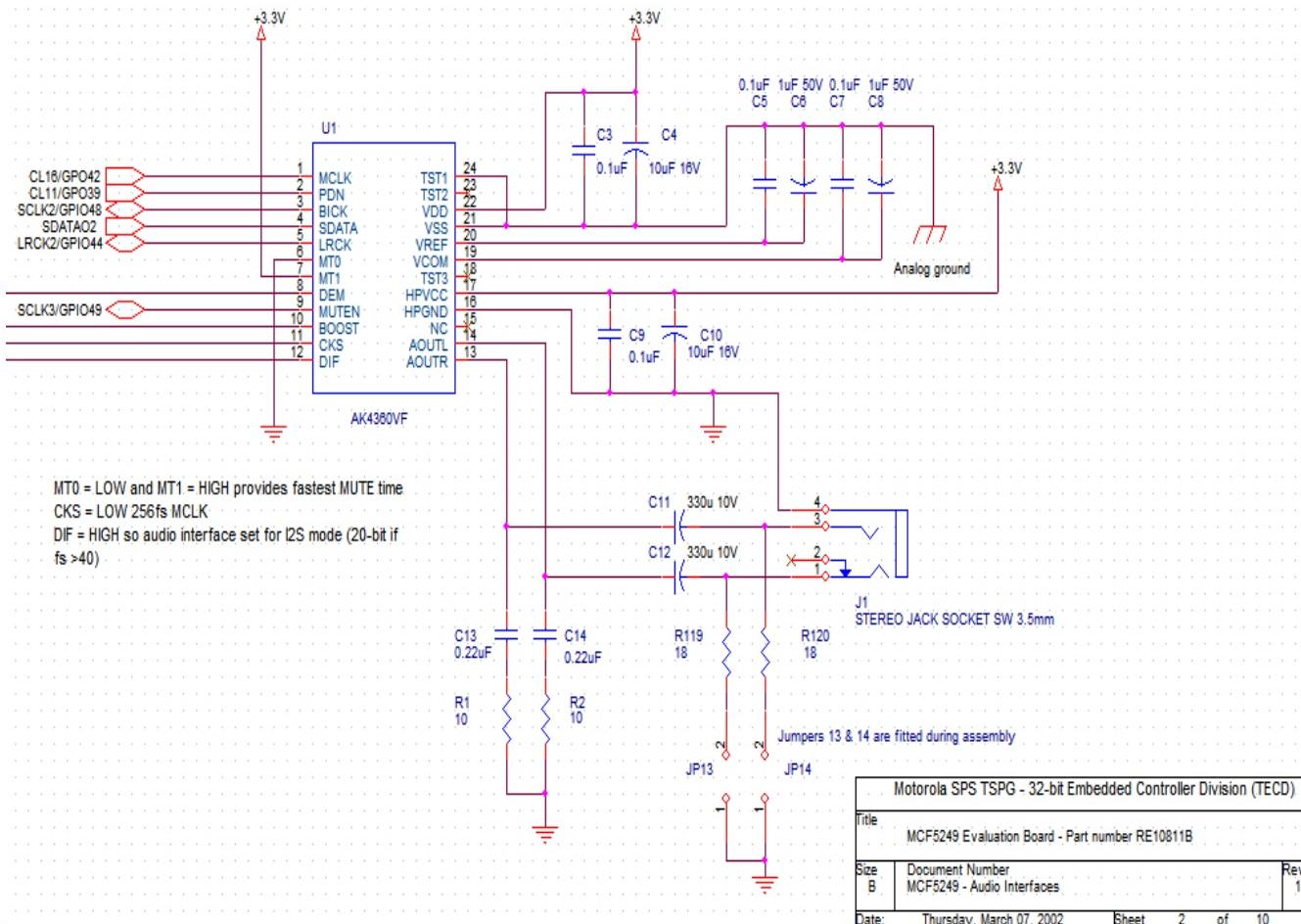
Figure 7. Audio Output Circuitry

The uClinux audio driver for the MCF5249 is located at /home/…/uClinux-dist/drivers/char/m5249audio.c, and it configures I2S2 to operate with a 44.1 kHz sampling frequency (LRCK signal), the common sampling rate value for CD-quality audio. If another sampling frequency is used (for example 8 kHz, which is used for voice applications), a different crystal frequency may be needed.

NOTE

The MP3 content is read via NFS from the server, and the decoder task decodes the file. In the MCF5249, an audio bus can receive and transmit audio information.
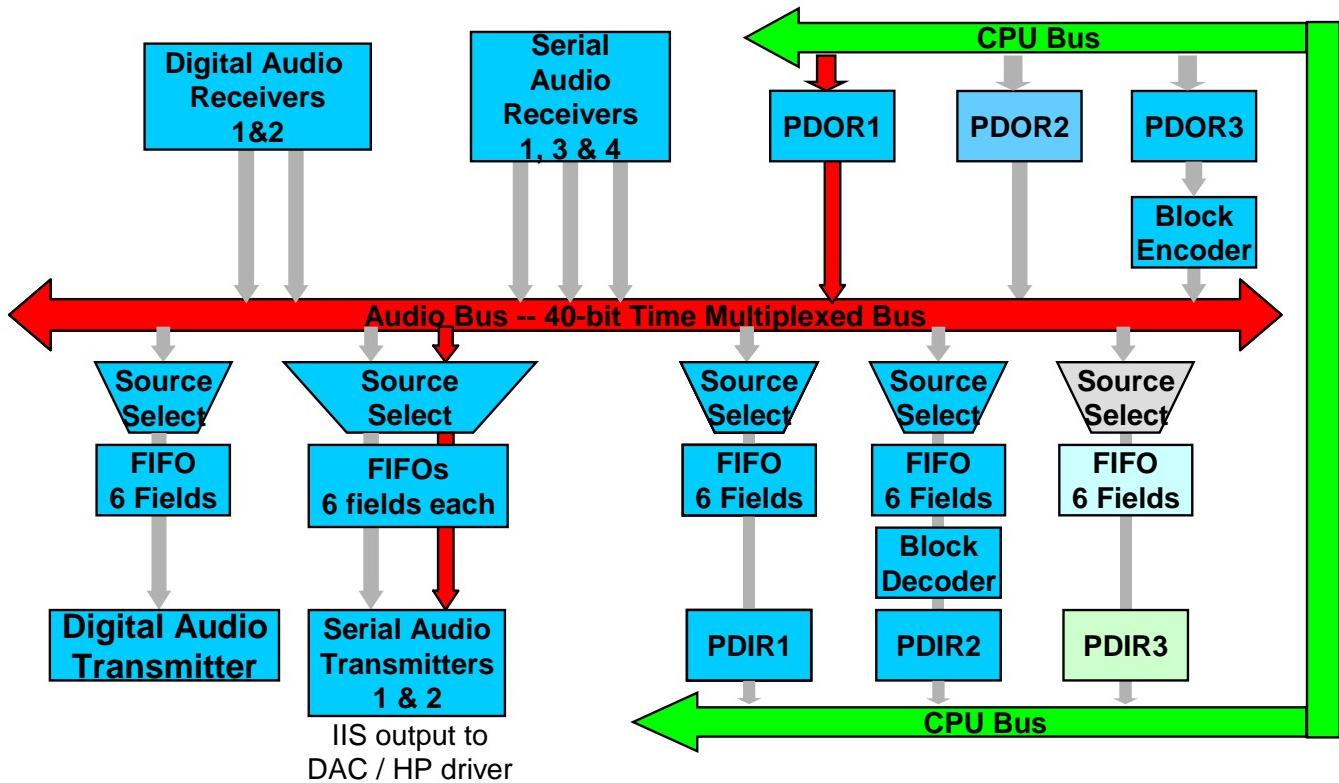
Figure 8. Digital Audio Path

The decoded data transfers from the CPU to one of three processor-data-output registers. In our case, PDOR1 transmits data from the CPU to the dedicated 40-bit audio bus. From the audio bus, you can select which interface outputs the audio: digital-audio interface or serial-audio interface. We use the serial audio interface (I2S2) to transmit data to the DAC. On the MCF5249, I2S1 is a bi-directional serial audio interface; I2S2 is output only; I2S3 and I2S4 are input-only.

2.3.2   Using Freescale's Optimized MP3 Decoder

After uClinux is running on the M5249C3 board, go to /bin directory (>cd /bin) and then ls. An MP3 player application comes as default with the uClinux build for MCF5249. We do not use it in this application because this version is not optimized. Freescale provides an optimized version of a MP3 decoder that uses the eMAC feature from the MCF5249. To gain more performance, place the MP3 decoder data and program into internal SRAM, so the critical time data and program from the decoder do not need fetched from external SDRAM. A sample rate converter (SRC) also allows playing MP3 files at these sampling rates: 8 kHz, 11 kHz, 12 kHz, 16 kHz, 22.05 kHz, 24 kHz, 32 kHz, or 48 kHz to 44.1 kHz

Memory usage of Freescale's MP3 decoder:

Table 1. MP3 Memory Usage

	Code	Stack	Tables and Data	Scratch
MP3 decoder	19.5 KB	1 KB	19.5 KB SRAM 6.5 KB DRAM	7 KB
SRC	13.2 KB	1 KB	5.9 KB SRAM 3.6 KB DRAM	2.3 KB

To download the MP3 decoder for uClinux, go to the MCF5249 product summary page
http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=MCF5249. Scroll down to the
libraries section (CFMP3LINUXDEC).

2.3.3   Adding the MP3 and SRC Libraries into the Kernel

The steps to add a new application into the uClinux kernel are shown at
/home/…/uClinux-dist/Documentation/Adding-User-Apps-HOWTO. Follow these steps to add the MP3
player application.

1. Change the current working directory to uClinux-dist directory.
2. Create a directory in ./user/ as uClinux_Motomp3.
3. Create a directory in ./user/uClinux_Motomp3 as lib.
4. Copy the following files to ./user/uClinux_Motomp3: mp3ld.ld, uClinux_Motomp3.c, uClinux_MP3D_decoder.h and Makefile
5. Copy the following files to ./user/uClinux_Motomp3/lib/: liblinuxmp3dec.a and liblinuxsrc.a
6. Add dir_$(CONFIG_USER_MP3_FREESCALE) += uClinux_Motomp3 to the appropriate place in Makefile in ./user/Makefile
7. Look for the original MP3PLAY application and place the CONFIG_USER_MP3_FREESCALE in the next line.
8. Add bool 'uClinux_Motomp3' CONFIG_USER_MP3_FREESCALE to the miscellaneous applications under the audio tools section in ./config/config.in

```
comment 'Audio tools'
#bool 'uClinux_Motomp3'CONFIG_USER_MP3_FREESCALE
bool 'mp3play'    CONFIG_USER_MP3PLAY_MP3PLAY
```

9. Add the following lines to ./config/Configure.help:

    CONFIG_USER_MP3_FREESCALE

    Optimized MP3 decoder

10. Go to menuconfig (>>make menuconfig).
11. Go to kernel/library/default Selection - - - >. Select.
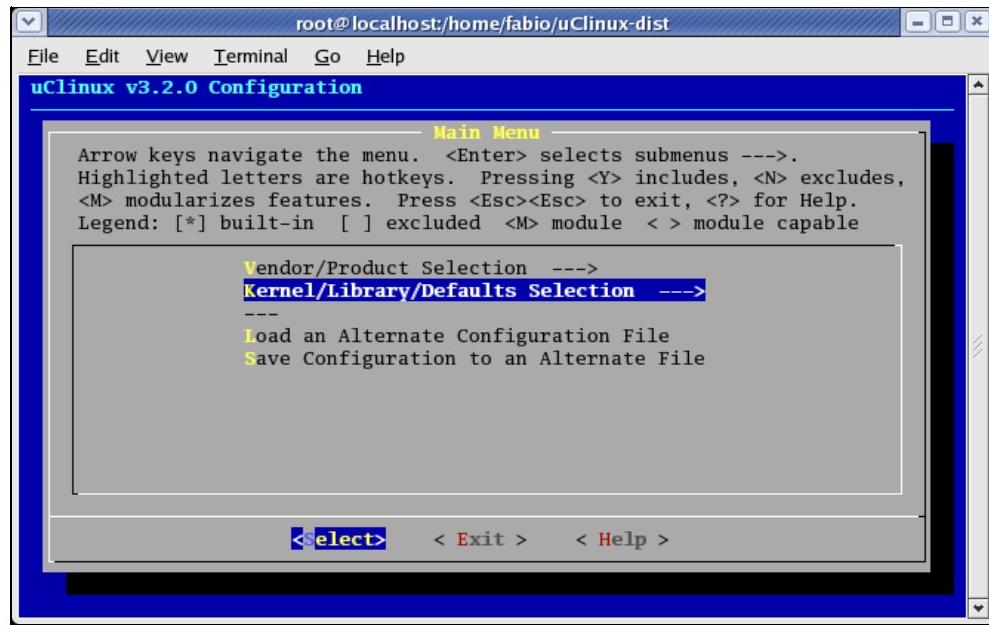
12. Mark customize kernel settings. Select.
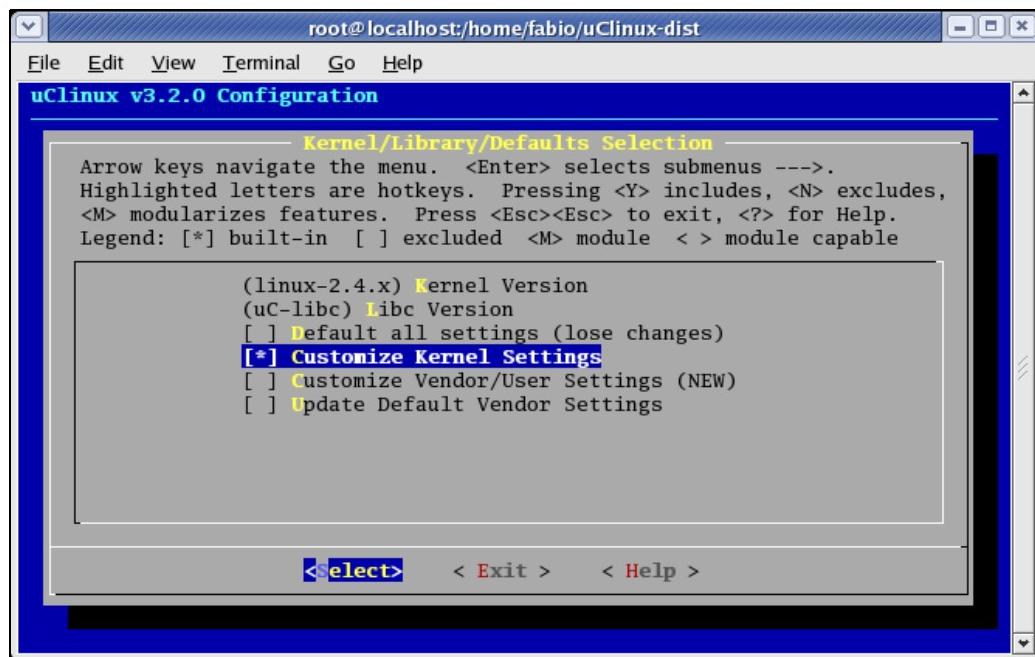
13. Exit.

14. Exit.

15. Yes for saving the kernel configuration.

16. Go to kernel hacking - - - > Select.
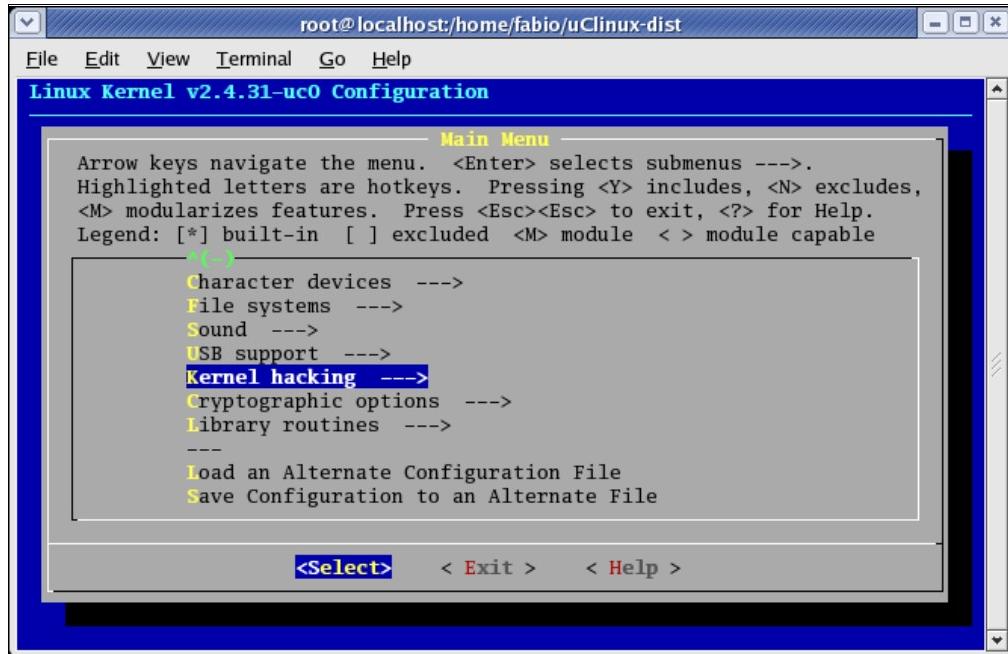
17. Mark non power-of-2 kernel allocator
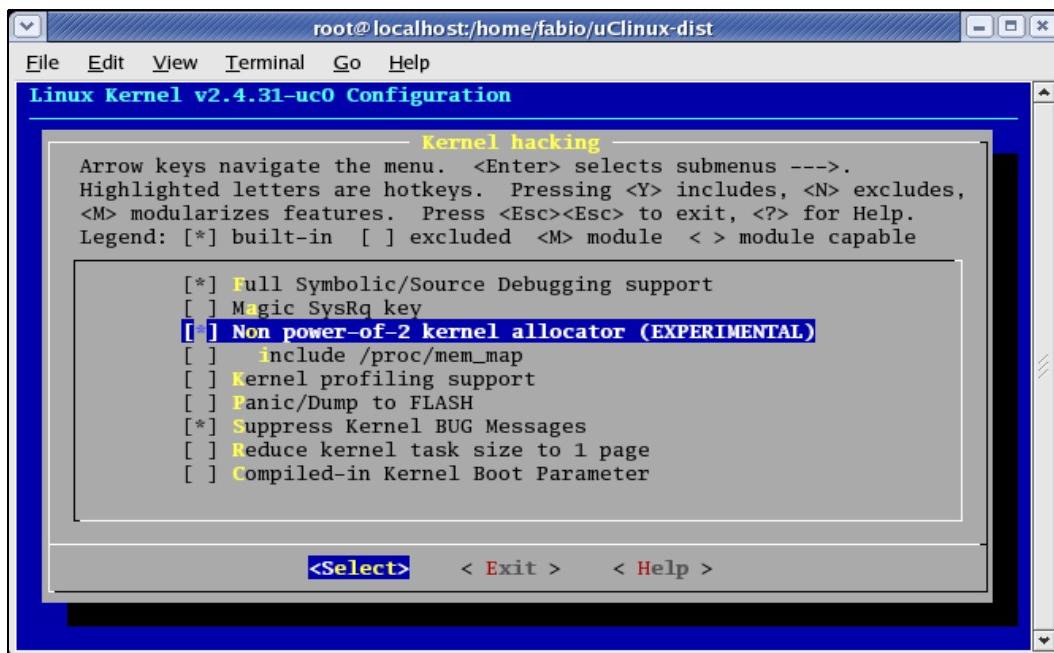
18. Exit.

19. Exit.

20. Yes for saving the kernel configuration. (>> make menuconfig)

21. Go to kernel/library/defaults selection - - - > Select.
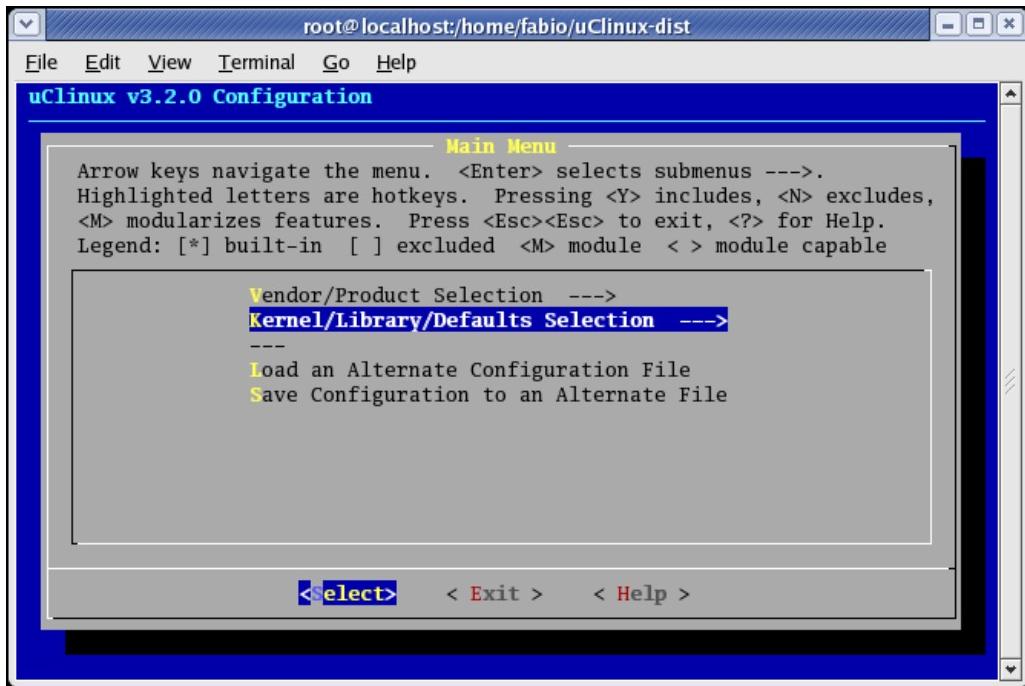
22. Mark customize vendor/user setting. Select.
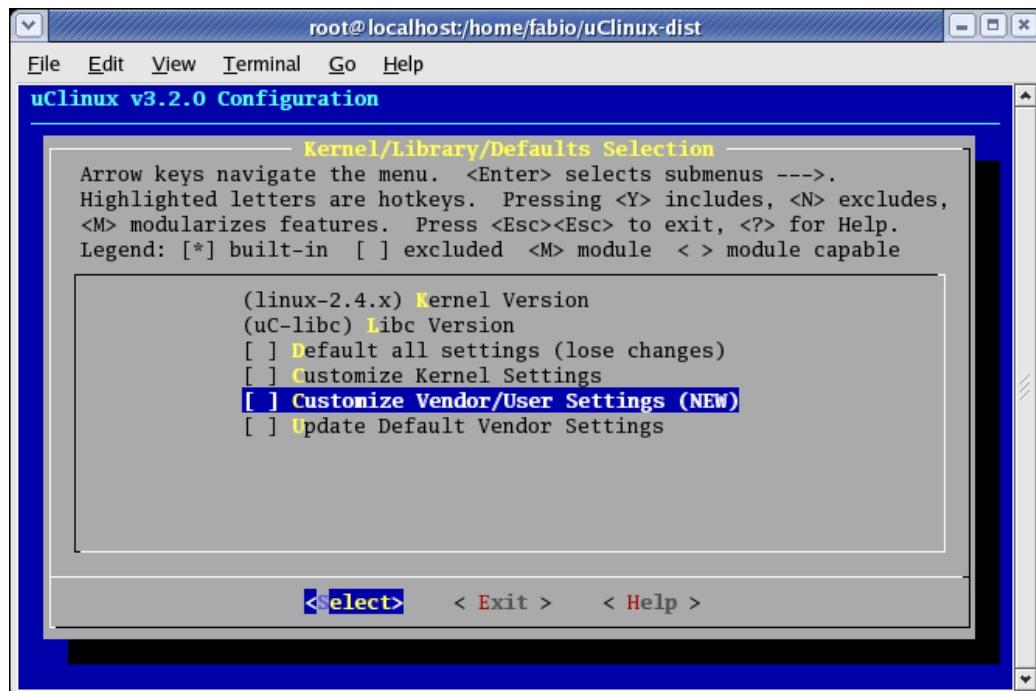
23. Exit.

24. Exit.

25. Yes for saving the kernel configuration.

26. Go to miscellaneous applications - - - > Select.
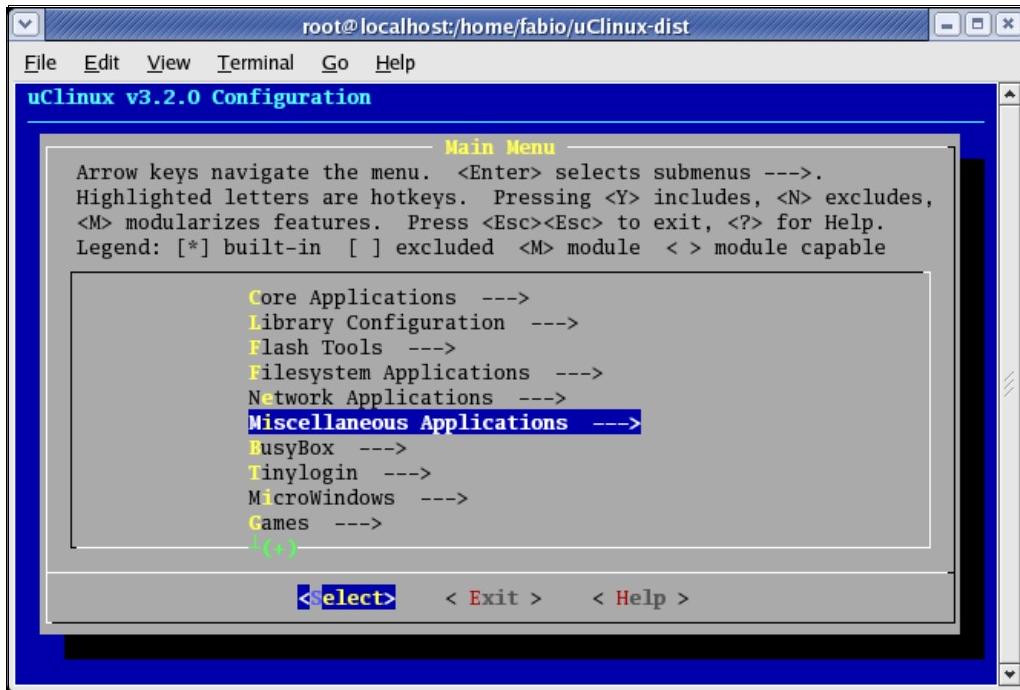
27. Scroll down to the - - - audio tools section. Mark uClinux_motomp3.
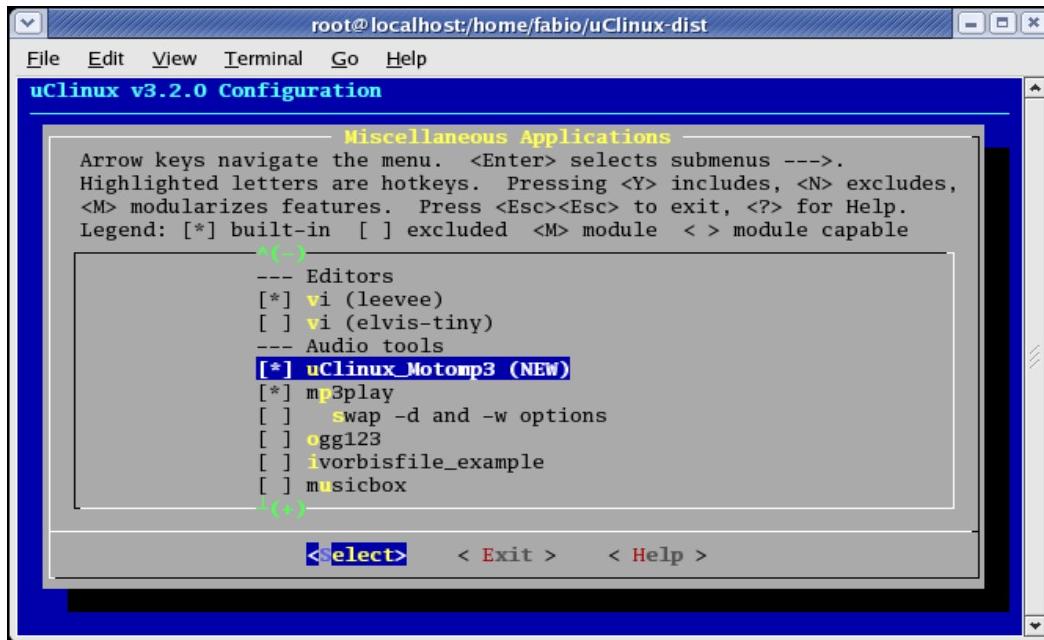
28. Exit.

29. Exit.

30. Yes for saving the kernel configuration.

31. For building the new image:

>> make dep; make

32. The new image (image.bin) is automatically copied to /tftpboot directory

33. Download the generated image.bin file to the M5249C3 (Section 2.2.1, "Generating a uClinux Image and Downloading it to the Target").

2.3.4   Exporting Files via NFS and Playing MP3 Files Remotely

Create a folder in the host side with MP3 content. Make it exportable via NFS. For RedHat 9.0 the /etc/exports is:

```
#
/mp3 192.168.0.*(rw)
```

The following directory structure created an MP3 in the host (/mp3):

> Beatles

> Deep Purple

> Eric Clapton

> Chorinho

Each directory above contains MP3 files.

For the target to access the MP3 folder in the host, the NFS service should run on the host and the following commands must be sent in uClinux:

portmap &

mount –o rsize=1024, wsize=1024 192.168.0.1:/mp3 /mnt

Now in the /mnt directory, all the content of /mp3 can be accessed from the M5249C3 board:

-> cd /mnt

->cd Beatles

-> ls –al

```
total 15516
drwxr-xr-x    2 root     root            4096 May 21 21:43 .
-rwxr-xr-x    1 root     root         4846741 Jan  8  2003 something.mp3
-r-xr-xr-x    1 root     root         5258013 Jan  8  2003 yesterday.mp3
-rwxr-xr-x    1 root     root         3813463 Mar  1 22:27 getback.mp3
```

> uClinux_Motomp3 something.mp3 &

NOTE

The ampersand (&) symbol denotes that the MP3 player application runs in background mode. This means other applications and uClinux commands can execute while the MP3 file is being decoded and played.

The above command decodes the something.mp3 file and the audio is played on the stereo audio output (connector J1).

3 Conclusion

This application note presented the steps for adding an optimized MP3 and sample rate converter (SRC) libraries into uClinux. uClinux supports many ColdFire device drivers, which can generate many applications such as hard-disk based MP3 players, SD and MMC MP3 players, Wi-Fi connectivity, etc. You can add LCD and keypads device drivers to the system. An overview of the powerful and flexible audio capabilities of the MCF5249/5250/5251 were also presented.

4 References

1. *MCF5249 ColdFire Integrated Microprocessor User Manual*
2. *M5249C3 Reference Board User Manual*
3. *MP3 Decoder on uClinux Demo User Manual*

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